

AFRL-VA-WP-TP-2003-327

**VALIDATION AND VERIFICATION OF
INTELLIGENT AND ADAPTIVE
CONTROL SYSTEMS (VVIACS)**



James Buffington

SEPTEMBER 2003

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Validation and Verification of Intelligent and Adaptive Control Systems (VIACS)



*James Buffington
September 17, 2003*

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OUTLINE



- INTRODUCTION
- APPROACH
- STATUS
- Q&A

TEAM



Team Member (Expertise)	VVIACS Assessment	VVIACS Development	VVIACS Evaluation
LM (Flight Certification)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
SSCI (Autonomous Control)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
GEGR (V&V)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Prof. Krogh (V&V)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Participation Level	High	Moderate	Low

A02-04851038

Vince Crum – AFRL - Government PM

Jim Buffington – LM Aero - Contractor PM

Clinton Plaisted – LM M&FC

Prasanta Bose – LM M&S

Bruce Krogh – Carnegie Mellon University

Tim Johnson – General Electric Global Research
Ravi Prasanth – Scientific Systems Company, Inc

Peter Stanfill – LM Aero

Greg Tallant – LM Aero

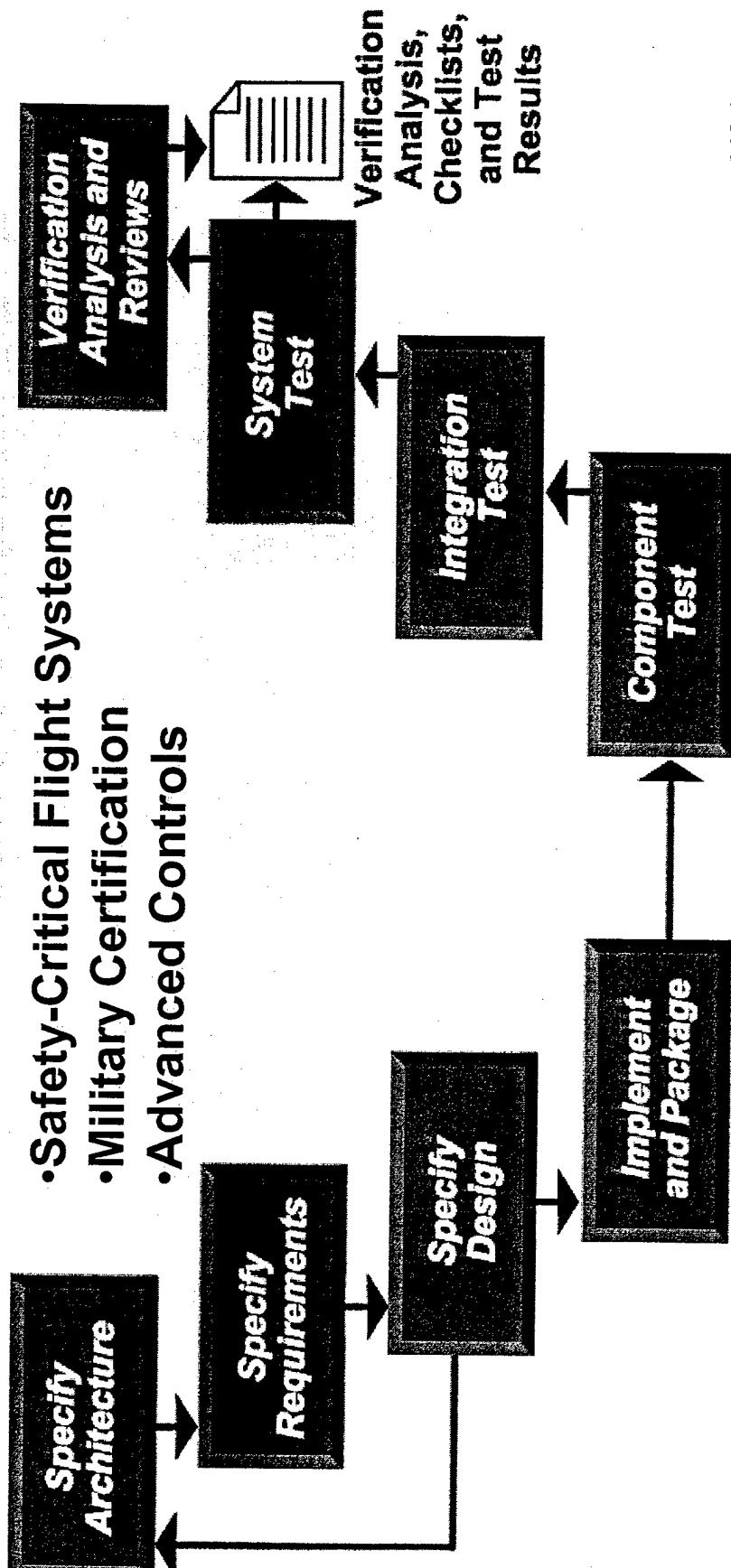
Barry Frazier – LM M&FC

Hunt Sutherland – General Electric Global Research

SCOPE

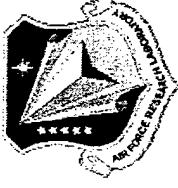


- Safety-Critical Flight Systems
- Military Certification
- Advanced Controls

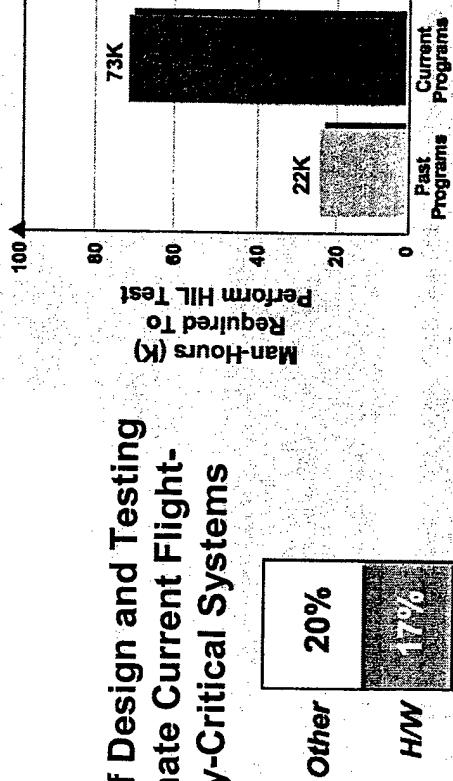


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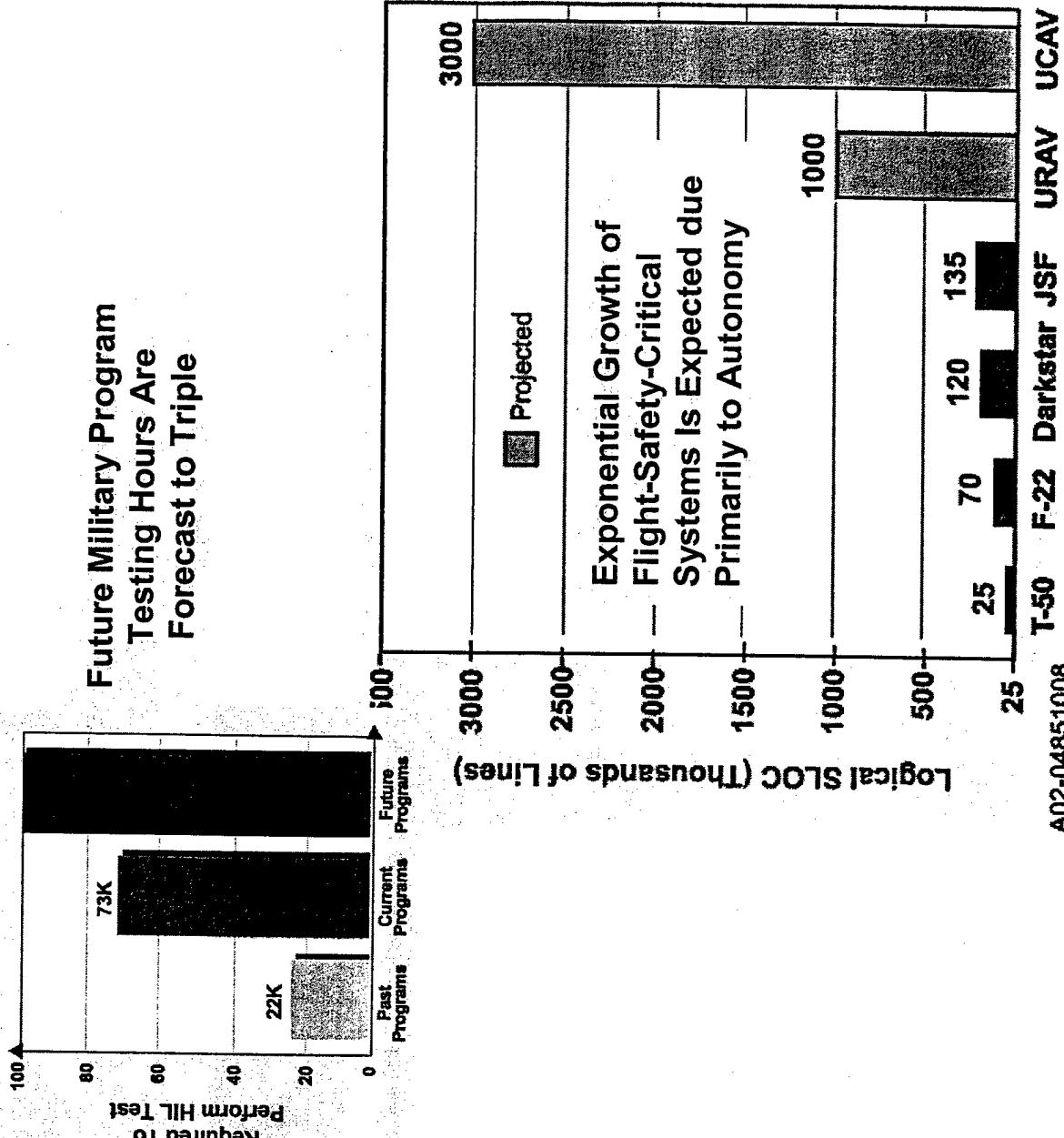
MOTIVATION



Costs of Design and Testing Dominate Current Flight- Safety-Critical Systems



Future Military Program Testing Hours Are Forecast to Triple



PURPOSE



GOAL:

Enable affordable development of future safety-critical flight systems with prescribed levels of safety and reliability.

OBJECTIVE:

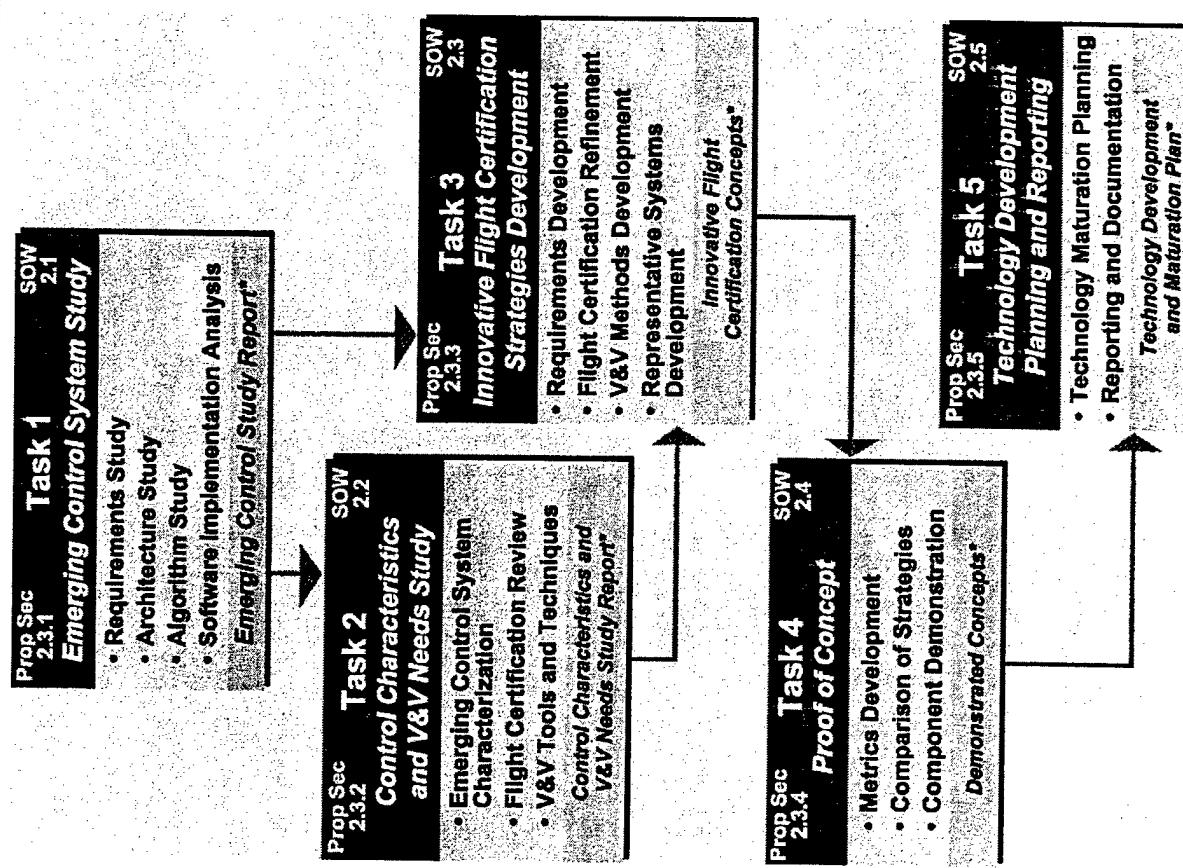
Study, develop, and demonstrate effective V&V technologies for advanced safety-critical control system flight certification.

- *Classify emerging safety-critical control systems according to fundamental attributes*
- *Develop and demonstrate preliminary V&V strategies that focus on critical flight certification schedule and cost points*
- *Identify high-payoff V&V process, tool, and method technologies for further development*

APPROACH:

- *Use Extensive Experience Base and Diverse Team to Develop Innovative Concepts*
- *Evaluate Concepts in Realistic Framework to Maximize Transition Success*

TASKS



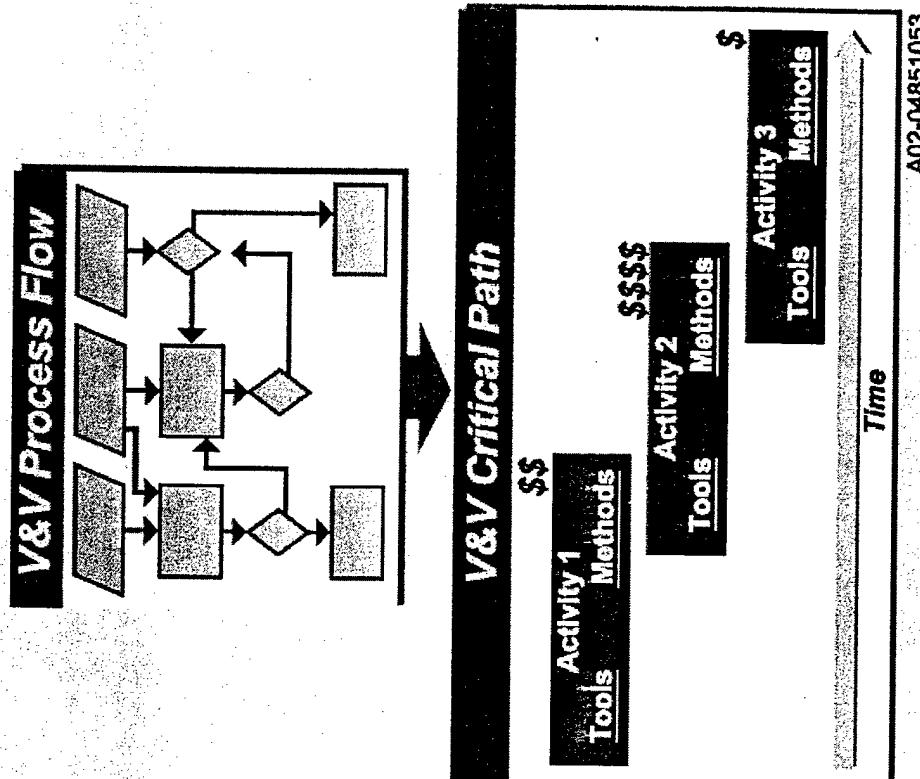
ASSESSMENT



- Emerging Control System Study
- Control System Characterization

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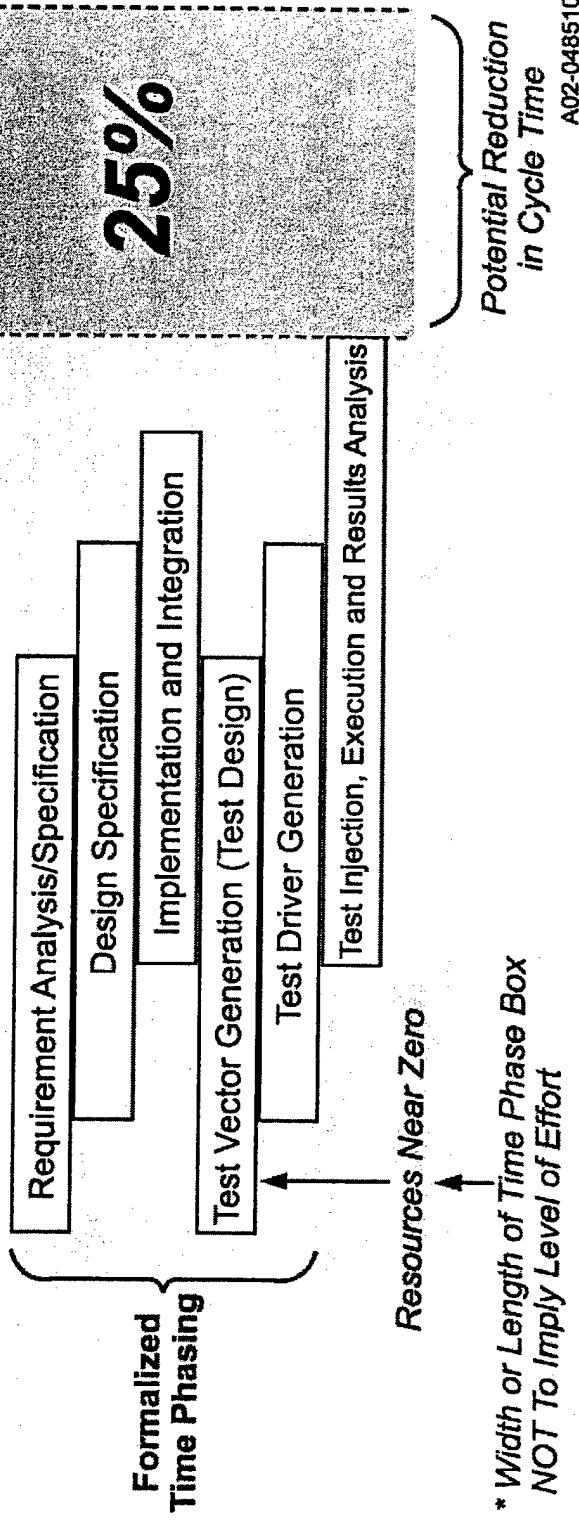
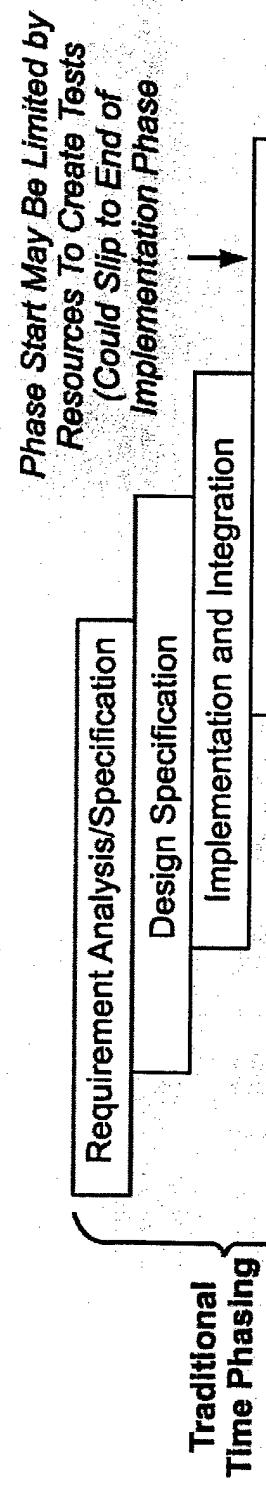
•V&V Needs Study



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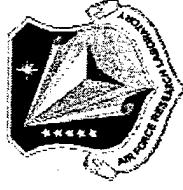
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DEVELOPMENT - Processes



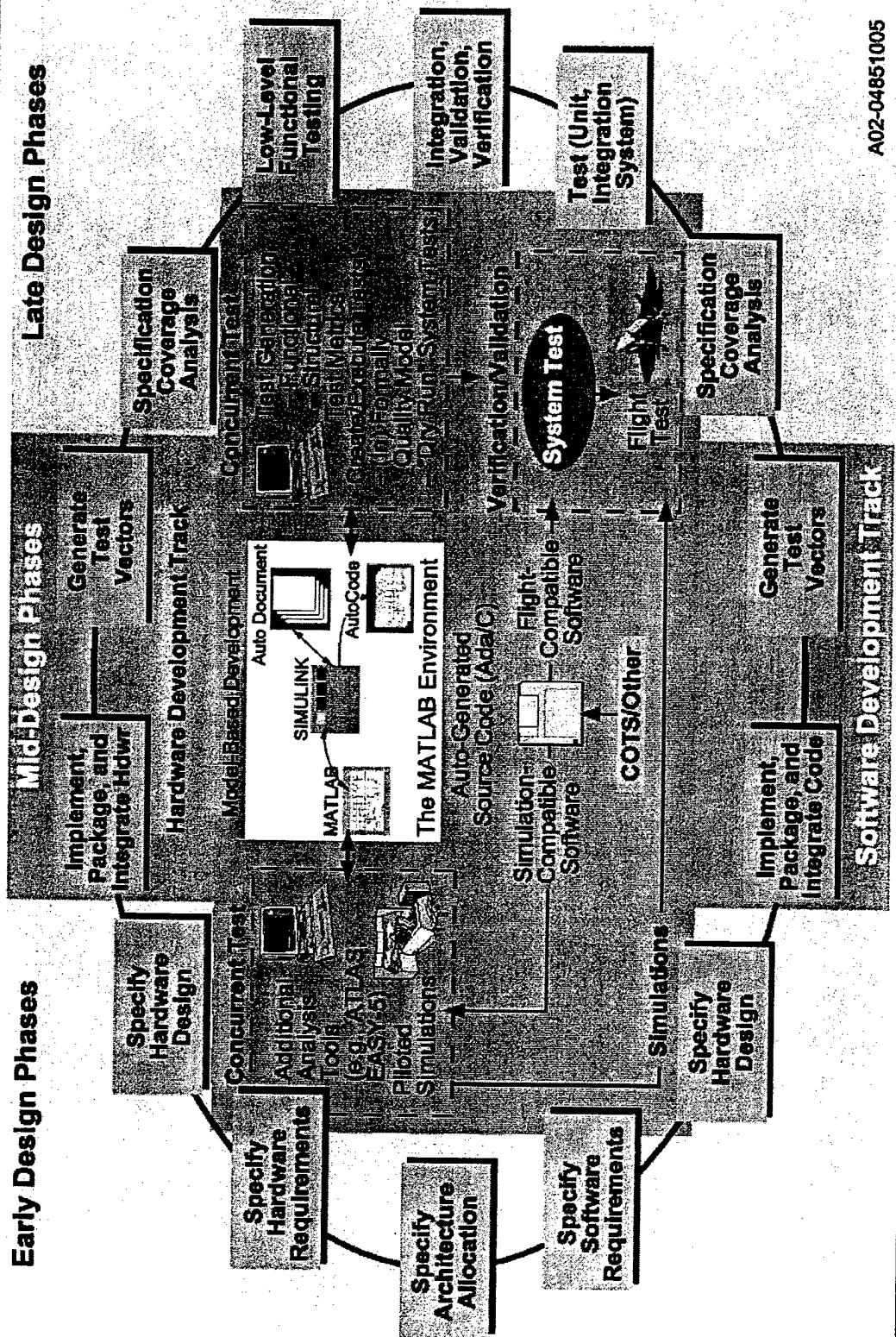
•Process Models

DEVELOPMENT - Methods



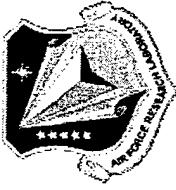
Early Design Phases

Late Design Phases

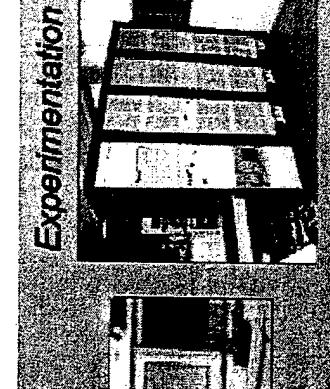
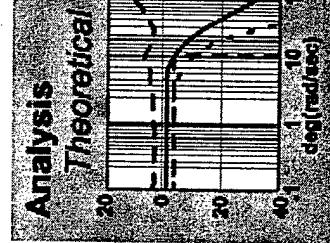


A02-04851005

EVALUATION - Proof of Concept



Metric Definition						
• Flight Safety						
• SW Dev Cost						
• LCC						
• Fit Cert Cost						
• Fit Cert Effort						
• Others TBD						



Assessment

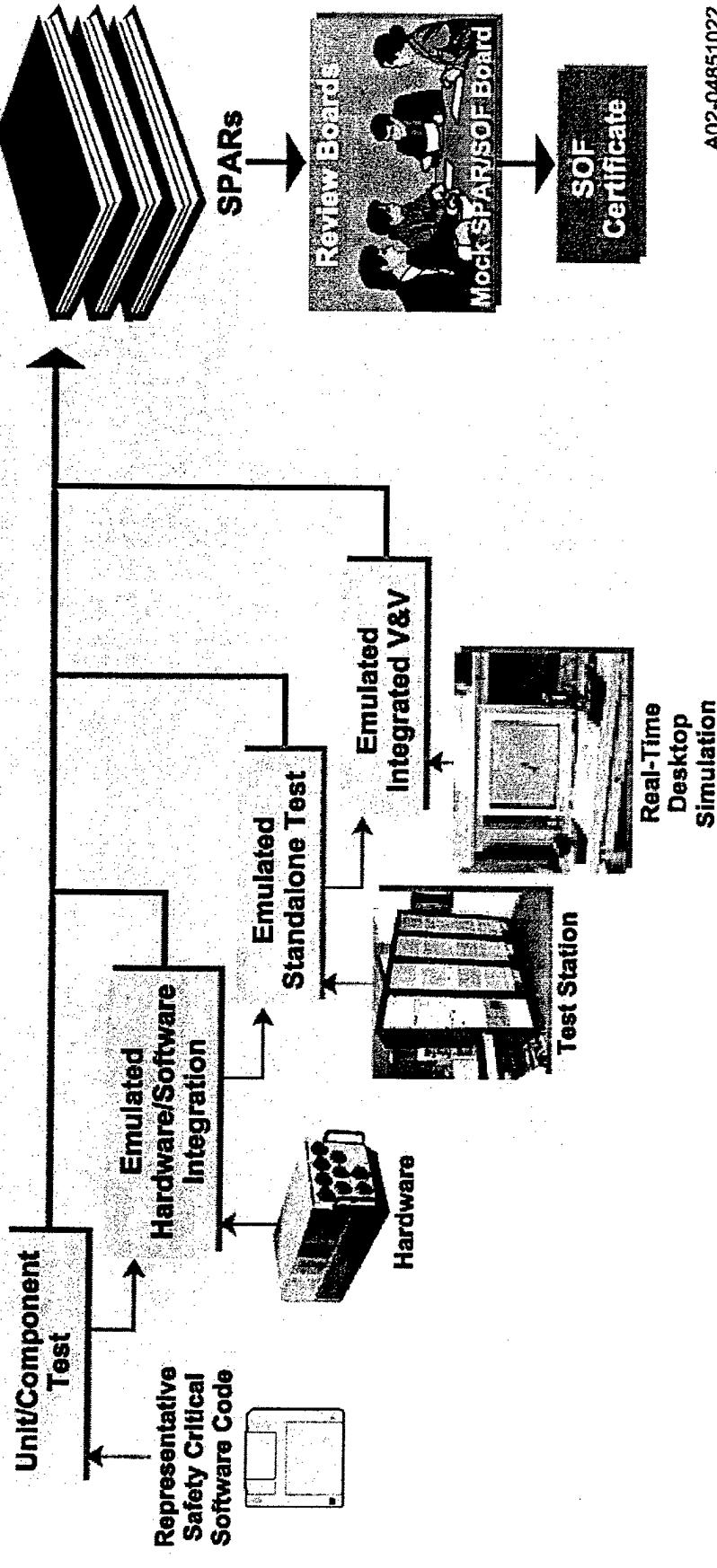
Innovative Flight Certification Concept	V&V Category	Current TRL	ROM SW Dev Cost (\$M)	ROM Certifications	Performance Metrics		Cost-Benefit Metrics	R/T	Score	Rank
					C DEV	Transition Metrics				
Concept A	Proc Tool	5	75	100	10	20	100	100	0.045	0.75
Concept B	Tool Math	6	6	9	10	10	100	100	0.054	0.93
Concept C	Math	5	12	18	10	25	100	100	0.057	0.93
Concept D	Tool	4	6	9	100	0	100	100	0.107	0.93
Concept E	Tool	6	1	1.5	0	25	100	100	1.001	1
Concept F	Proc	4	12	100	D	100	100	100	0.051	0.33
Concept G	Proc	5	120	100	100	25	100	100	0.113	0.1
Concept H	Proc,Math	3	6.5	7.50	100	25	100	100	0.113	0.17
Concept I	Proc,Tool,Math	3.5	16	84	100	7.5	100	100	0.056	0.5
Concept J	Proc,Tool,Math	3	20	37.5	100	D	100	100	0.059	0.467

Most Promising Concepts for Demonstration

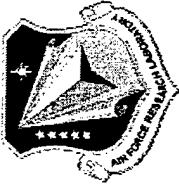
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EVALUATION – Safety of Flight Certification Model



EVALUATION - Planning

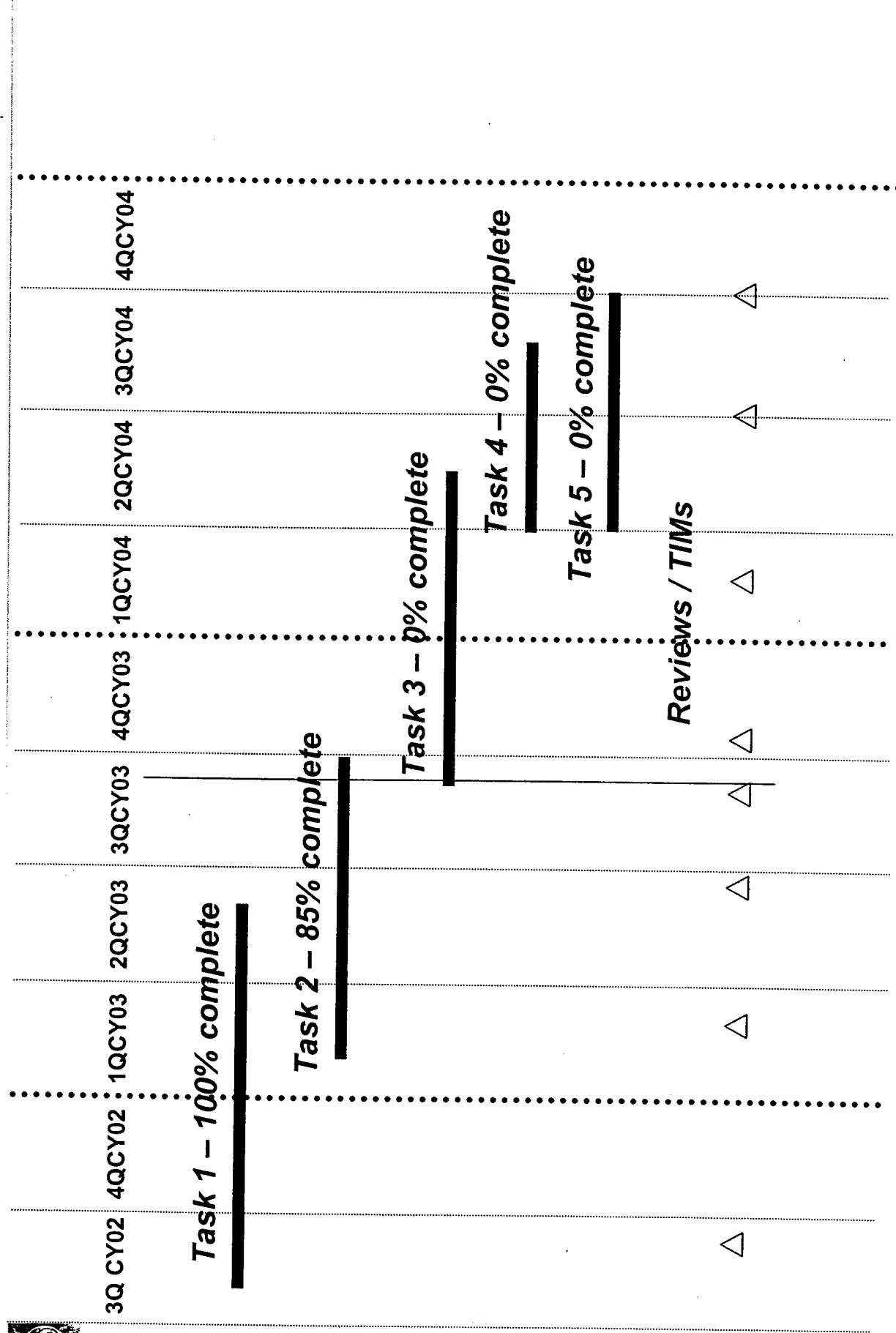


Tech Risk Level

		1. Exit Criteria		2. Exit Criteria		3. Exit Criteria		4. Exit Criteria		5. Activities & Cost		6. Activities & Cost	
		TRL 1		TRL 2		TRL 3		TRL 4		TRL 5		TRL 6	
		High	Moderate	Moderate	Low	Low	Low	Low	Low	Low	Low	Low	Low
		Significance	Impact	Impact	Impact	Impact	Impact	Impact	Impact	Impact	Impact	Impact	Impact
High													
Moderate													
Minor													
Low													
CY	1999	2000	2001	2002	2003	2004	2005						
Milestones	MS1	MS2	MS3										

AD2-04851020

STATUS – Program Schedule



STATUS - Database Tool



Microsoft Access - [Main Menu : Form]

File Edit View Insert Format Records Tools Window Help

Type a question for help

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GLOSSARY

Task 1 - Emerging Control Systems Study

Task 2 - Control Characterization and IV Needs

Quick Access

Validation & Verification of Intelligent and Adaptive Control Systems

Validation & Verification of Intelligent and Adaptive Control Systems

TECHNICAL

Record: 14 of 14 Form View

A screenshot of a Microsoft Access form. The title bar says "Microsoft Access - [Main Menu : Form]". The menu bar includes "File", "Edit", "View", "Insert", "Format", "Records", "Tools", "Window", and "Help". A toolbar with buttons for "New", "Open", "Save", "Print", "Find", "Replace", "Sort", "Filter", and "Exit" is visible. The main area contains a large image of a Lockheed Martin F/A-18 Hornet fighter jet in flight. Overlaid on the image is text: "Validation & Verification of Intelligent and Adaptive Control Systems" and "Validation & Verification of Intelligent and Adaptive Control Systems". In the bottom right corner of the image, the word "TECHNICAL" is printed. The bottom of the screen shows a status bar with "Record: 14 of 14 Form View".

Record: 14 of 14 Form View

STATUS – Control System Database



Task 1 Database

Microsoft Access - [temp]

Main Menu

File Edit View Insert Format Records Tools Window Help

9 B Y U Z A L D E F G H I J K L M N P Q R S T V X

Type a question for help > - & X

Project Downselect

Category	Data Fields	Instructions	Reference Material
Program Name	ATIGAS/AGCAS	Enter direct name of program or project	
Application	Military Aircraft	Choose best selection from menu	
Time	Past	Past, Current, Planned, or Future Program	
Technology Readiness Level	7	Choose best selection from menu	TRL chart
Maturity	Prototype	Choose best selection from menu	
Information Source	Mechanization / Implementation	Level of documentation available for further study	
Reliability of Information	TAR	Choose best selection from menu	
Emerging Control Level	Medium	Choose best selection from menu	ECL chart
Primary Approach Attribute	Classical	Enter a few words that describe the base of the approach and support the Emerging Control Level	
Control Domain	Guidance	Choose best selection from menu	Control Domain chart
Autonomous Control Level	1	Choose best selection from menu	ACL spreadsheet
System State	Hybrid	Choose best selection from menu	System State chart
WIGS Owner	LM Aero	Choose best selection from menu	
Developer	LM Aero	Enter the prime contractor of the program	
Autonomy		Enter a few key words for the project	
Application		Enter any additional comments	

Record: 14 of 40 Form View

Primary Scoring Factors

Other Factors:
Maturity
Developer
Autonomy
Application

STATUS - Emerging Control Systems



ECS PROJECT

AIMSAFE / RESTORE

ICARUS

LOCAAS

Enhanced GNC Algorithms

XACT

Software Enabled Control

EDCS F-16 Autopilot

Engine Control Cutoff Mode

Intelligent Engine Control

Intelligent Maintenance Advisor for Turbine Engines

Formation Flying Spacecraft

DESCRIPTION

Integrated Management, Adaptive Control

Intelligent Autonomy

Autonomous Control

Dynamic Programming Optimization

Adaptive Failure Management

Optimal Trajectory Generation

Outer Loop Hybrid Control

Nonlinear Hybrid Control

Intelligent Failure Management

Model-based Health Management

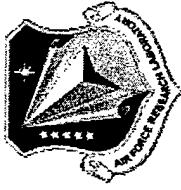
Multi-vehicle Control

STATUS - Summary



- Emerging Control System Study (Task 1)
 - Completed study and organization of project data (48 projects)
 - Completed project data collection and insertion into database tool
 - Completed project data down-select to 10 Emerging Control Systems
 - Developed preliminary project glossary
- Control Characterization and V&V Needs Study (Task 2)
 - Developed detailed task plan
 - Review of LM Aero FC/VMS development processes and program plans
 - Developed preliminary representative time-phased critical-path representation of development process
 - Completed Control Characterization of control system projects with emphasis on Emerging Control Systems

Q&A



Questions?